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The Case for Technology in Advanced Distributed Learning

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This paper summarizes evidence on the value of Advanced Distributed Learning (ADL) used to provide military education and training. ADL is an enabling technology and makes few distinctions between education and training. For brevity, education and training are together termed 'instruction' in this paper.

This paper does not discuss evidence concerning the use of ADL technology to aid performance. ADL performance aiding can both reduce costs and increase effectiveness. It is readily available from ADL materials used for instruction. It is the topic of a paper that is a companion to this one. Both papers were prepared for the NATO Working Group on Individual Training and Educational Development.

The US ADL initiative is intended to ensure access to high quality education, training, and performance aiding that is tailored to individual needs and available anytime, anywhere to whomever needs it. As other countries pursue ADL for their own purposes, they may well adopt different perspectives. The US goal is stated here to suggest some issues to be considered. Notably, this goal is viewed as something that can only be achieved affordably, and thereby made feasible, through the use of technology – specifically computer technology.

The current argument for ADL instruction and interactive ADL technology may be roughly summarized as the following:

(1) Tailoring instruction (education and training) to the needs of individual students is imperative for efficient learning, but such efficiency has been unaffordable because it requires one instructor for each student.

(2) ADL instruction and technology can, in many cases, make this instructional imperative affordable and, thereby, feasible.

(3) ADL instruction is more effective than current instructional approaches in many cases across many subject matters.

(4) ADL instruction is generally less costly than current instructional approaches, especially when many students or expensive devices are involved.

(5) ADL instruction is often the most cost-effective alternative for distributing instruction and for sustaining and enhancing the capabilities and readiness of military personnel after they are assigned to duty stations.

(6) ADL instruction will become increasingly affordable and instructionally effective with the development and use of standardized instructional objects.

These arguments have been made for ADL over the last 5-7 years. This paper merely attempts to collect and summarize these points as succinctly as possible.

It should be emphasized that ADL capabilities can be used either by individuals or groups of individuals working in collaboration. The capabilities can be used in residential classrooms, remote classrooms, or any remote (distributed) location – workplace, home, or elsewhere – outside of classroom walls.

Further, it is neither a goal nor an expectation that ADL instruction will replace all human instructors. They will continue to be needed. However, their roles and responsibilities remain perennial issues in the design and implementation of ADL instruction. Finding the right balance is important.

The arguments in favor of ADL instruction are credible, but the evidence remains incomplete. More research, evaluations, and data are needed. However, the available evidence may be sufficient to shift the issue from "Why should we undertake ADL instruction?" to "Why should we not undertake ADL instruction?"

The value and affordability of tailored instruction.

The argument for ADL instruction usually begins with an issue that is separate from the use of technology. It concerns the effectiveness of classroom instruction, involving one instructor for 20-30 students, compared to individual tutoring, involving one instructor for each student. Some empirical results from comparisons of this sort are shown in Figure 1 taken from Bloom (1984).

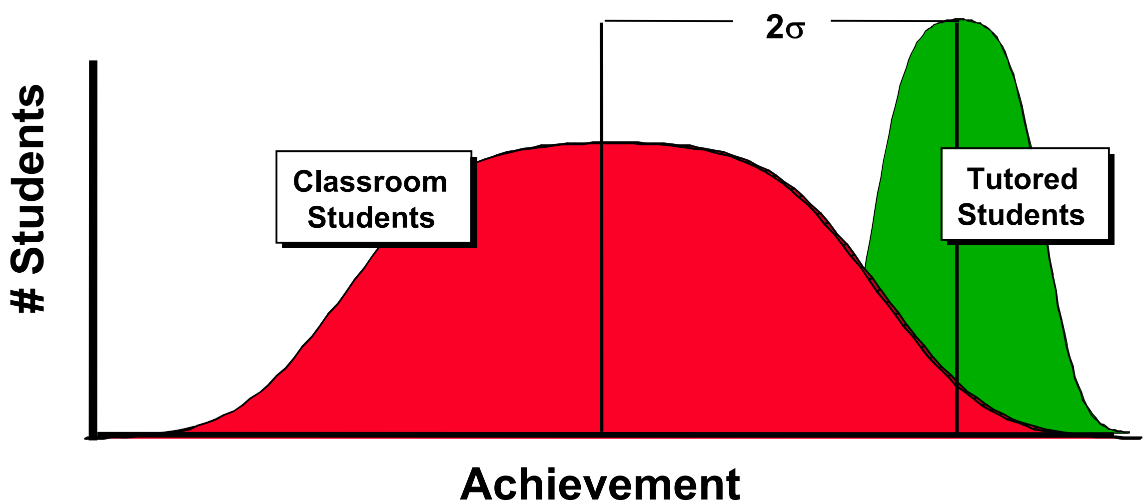

Figure 1. Individual Tutoring Compared to Classroom Instruction

Bloom combined findings from three empirical studies comparing one-on-one tutoring with one-on-many classroom instruction. That such comparisons would show that the tutored students learned more is not surprising. What is surprising is the size of the difference in learning. Overall, as the figure suggests, it was two standard deviations. This finding means for example and roughly that, with instructional time held fairly constant, one-on-one tutoring raised the performance of mid-level 50th percentile students to that of 98th percentile students. These and similar empirical research findings suggest that differences between one-on-one tutoring and typical classroom instruction are not only likely, but very large.

Why then don't we provide these benefits to all students? The answer is straightforward and obvious. With the exception of a few critical skills, such as aircraft piloting and surgery, we can't afford it. The primary issue is cost.

What accounts for the success of one-on-one tutoring? Fundamentally, its success appears to be due to two capabilities: (1) the capability of tutors and their students to engage in many more interactions per unit of time than is possible in a classroom, and (2) the capability of tutors to adapt their presentations and interactions on demand and in real time to the needs of their students. Both of these capabilities can be provided by interactive, computer-based ADL technologies.

Interactivity

With regard to the first tutorial capability concerning intensity of instructional interaction, Graesser and Person (1994) reported the following:

- Average number of questions by a teacher of a class in a classroom hour: 3
- Average number of questions asked by a tutor and answered by a student during a tutorial hour: 120-145
- Average number of questions asked by any one student during a classroom hour: 0.11
- Average number of questions asked by a student and answered by a tutor during a tutorial hour: 20-30

These data show great differences in interactivity between two approaches (tutorial and classroom instruction) that also show great differences in instructional effectiveness. This level of interactivity, by itself, may account for a substantial portion of the success of tutorial over classroom instruction.

Is this level of interactivity found in instruction using ADL technology? One early study found that students taking reading and arithmetic instruction were answering 8-10 questions a minute (Fletcher 1997). This level of interactivity extrapolates to 480-600 such questions an hour, if students were to sustain this level of interaction for 60 minutes.

These students worked with the computer-based materials in 12 minute sessions, which extrapolates to 96-144 individually selected and rapidly assessed questions the students received each day for each subject area. This level of interactivity is certainly comparable to what they would receive in one-on-one tutorial instruction.

Pace

With regard to the second tutorial capability, it is worth noting that tutors adjust the content, sequence, and difficulty of instruction to the needs of their students. All these adjustments, relate to pace – the rate or speed with which students are allowed to proceed through instructional material.

Many classroom instructors have been struck by the differences in the pace with which their students learn. Their observations are confirmed by research. For instance, consider some findings on the time it takes for different students to reach the same instructional objectives:

- Ratio of time needed by individual students to reach mathematics objectives: 4 to 1 (Suppes, Fletcher, and Zanotti, 1975; 1976)

- Overall ratio of time needed by individual students to reach objectives in a variety of subjects: 5 to 1 (Gettinger, 1984)

- Ratio of time needed by undergraduates in a major research university to learn a programming language: 7 to 1 (Private communication, Corbett, 1998)

Differences among students in the speed with which they learn are not surprising, but (as with tutoring) the magnitudes of the differences are surprising. These differences do not directly stem from ability. The students in Corbett's research university average well above the 80th percentile in their admission tests, yet the differences in time they require to learn a programming language remain large. Instead, research has found that the speed with which different students reach instructional objectives is largely determined by prior knowledge (Tobias, 1989). Students in military education and training bring with them a wide variety of backgrounds and life experiences. The ability to adjust the pace of instruction to their individual needs may be especially important for them.

The challenge this diversity presents to classroom instructors is daunting. Typically they must focus on their slower students and leave the faster students to fend for themselves. This is especially true in training settings where the primary task is to enable as many students as possible to cross a specific threshold of knowledge and skill. ADL technology alleviates this difficulty by tailoring the content, sequence, and difficulty – and thereby the pace – of instruction to the needs of individual students. The students then proceed as rapidly or as slowly as needed. Each student can skip what he or she already knows and concentrate on what is yet to be learned. The result is that practically any group of students using ADL technology will reach their instructional objectives sooner than they will in a classroom with one teacher and many students.

Payoff: Time Savings

One of the most stable findings in comparisons of technology-based instruction with conventional instruction using lecture, text, and experience with equipment concerns instruction time savings. These findings are presented in Table 1.

Table 1. Percent Time Savings for Technology-Based Instruction

Study (Reference)	Number of Studies Reviewed	Average Time Saved (Percent)
Orlansky and String (1977) (Military Training)	13	54
Fletcher (1991) (Higher Education)	8	31
Kulik (1994) (Higher Education)	17	34
Kulik (1994) (Adult Education)	15	24

As the table shows, Orlansky and String (1977) reported that reductions in time to reach instructional objectives averaged about 54 percent in their review of technology used in military training. Fletcher (1997) reported an average time reduction of 31 percent in 6 assessments of interactive videodisc instruction applied in higher education. Kulik reported time reductions of 34 percent in 17 assessments of technology used in higher education and 24 percent in 15 assessments of adult education (Kulik, 1994). All these reviews reviewed different sets of evaluation studies. Overall, it seems reasonable to expect technology-based instruction to reduce the time it takes students to reach a variety of objectives by about 30 percent.

Payoff: Costs

Because ADL technology can increase interactivity and adjust pace for individual students, it saves instructional time. Such time savings reduce instructional costs. What might these cost savings amount to? Such reductions in time to learn produce reductions in expenditures for instructor pay and allowances, student pay and allowances, temporary duty costs, training equipment costs, and installation support costs—among the measurable cost categories. As the figure suggests, these cost savings can be substantial.

For instance, the United States military spends about $4 billion a year on residential, specialized skill training. This is the "schoolhouse" training personnel receive after "basic" or accession training. It is the training that qualifies them for the many technical jobs (e.g., wheeled vehicle mechanics, radar operators, avionics technicians, medical technicians) needed to perform military operations. It does not include the costs of aircraft pilot training or training that occurs in units.

Figure 2 illustrates the cost savings in specialized skill training that would occur if training time were reduced. The figure shows the annual reductions in costs that would result if instruction time were reduced by 30 percent for 20, 40, 60, and 80 percent of the US military personnel who complete specialized skill training each year. For instance, if the US were to reduce by 30 percent the time to train 20 percent of the personnel undergoing specialized skill training, it would save over $250 million per year. If it were to do so for 60 percent of the personnel undergoing specialized skill training, it would save over $700 million per year, an appreciable amount by almost any standard.

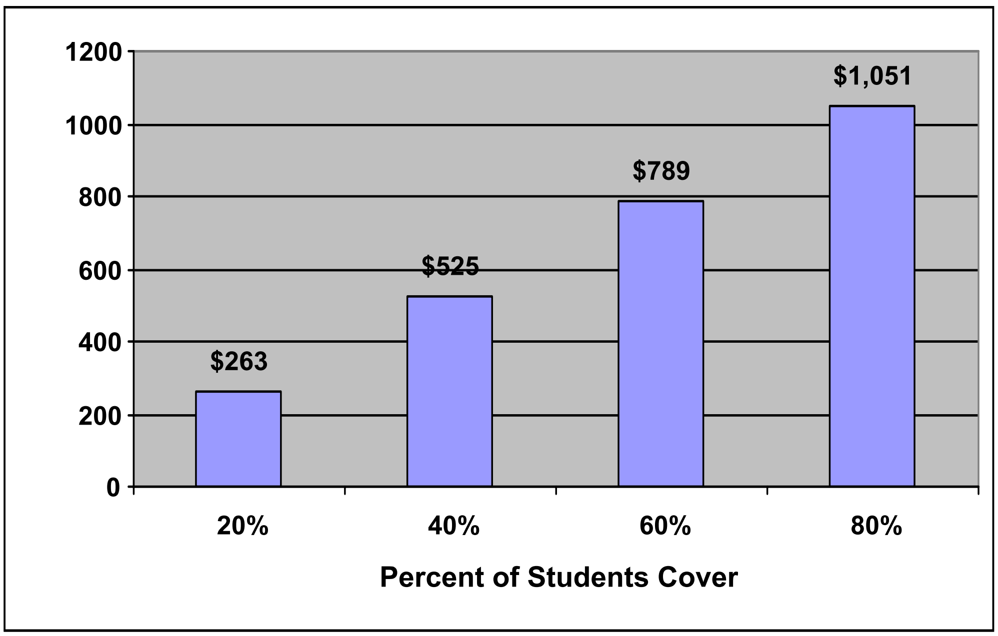

Figure 2. Cost Savings in Specialized Skill Training Assuming a 30 Percent Reduction in Training Time.

Saving 30 percent of training time may be a conservative target. Commercial enterprises that develop technology-based instruction for the Department of Defense (DoD) regularly base their bids on the expectation that they can reduce instructional time by 50 percent. Noja (1991) has reported time savings through the use of technology-based instruction as high as 80 percent in training operators and maintenance technicians for the Italian Air Force.

Additionally, and perhaps more importantly for military applications, ADL technology prepares individuals more quickly for operational duty. In this way it acts as a force multiplier, increasing readiness and operational effectiveness without increasing personnel costs.

Instructional Effectiveness

Do these savings in time come as the expense of instructional effectiveness? Research data suggest the opposite. Empirical results suggest that the technology used by ADL increases instruction effectiveness. Noja's 1987 findings are representative. In comparing conventional instruction in electronics with technology-based instruction for Italian Air Force technicians, he found a reduction in training time of 3 weeks (from 8 to 5 weeks), equivalent student achievement for electronic theory, and substantial improvements in student achievement for electronic applications.

A single study does not provide final answers, but many studies can be aggregated to suggest conclusions. This aggregation is usually done using "meta-analysis" (analysis of analyses) with an estimation of effect sizes. Roughly, effect sizes are normalized measures found by subtracting the mean from one collection of results (e.g., a control group) from the mean of another (e.g., an experimental group) and dividing the resulting difference by an estimate of their common standard deviation. Because they are normalized, effective sizes can be averaged to give an overall estimate of effect from many separate studies undertaken to investigate the same phenomenon. Figure 3 shows effect sizes from several reviews of studies that compared conventional instruction with technology-based instruction.

In Figure 3 'Computer-based instruction' summarizes results from 233 studies that involved straightforward application of computer presentations that used text, graphics, and some animation—as well as some degree of individualized interaction. The effect size of 0.39 standard deviations suggests, roughly, an improvement of 50th percentile students to the performance levels of 65th percentile students.

'Interactive multimedia instruction' involves more elaborate interactions adding more audio, more extensive animation, and (especially) video clips. These added capabilities evidently increase achievement. They show an average effect size of 0.50 standard deviations compared with an effect size of 0.39 for typical computer-based instruction. An effect size of 0.50 for interactive multimedia instruction suggests an improvement of 50th percentile students to the 69th percentile of performance.

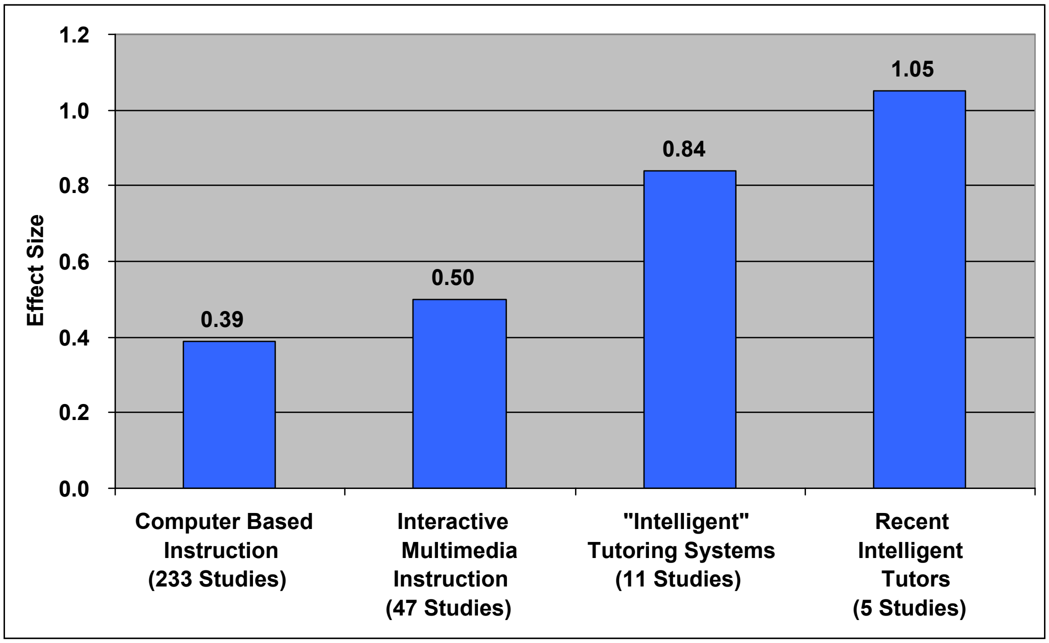

Figure 3. Some effect sizes for studies comparing technology-based instruction with more conventional approaches.

‘Intelligent tutoring systems’ involve a capability that has been developing since the late 1960s, but has only recently been expanding into general use. In this approach an attempt is made to directly mimic the one-on-one dialogue that occurs in tutorial interactions. The key component of these systems is that computer presentations and responses are generated in real-time, on demand and as needed or requested by learners. Instructional designers do not need to anticipate and pre-store them. This approach is computationally more sophisticated and more expensive to produce than standard computer-based instruction. However its costs may be justified by the increase in average effect size to 0.84 standard deviations, which suggests, roughly, an improvement from 50th to 80th percentile performance.

Some more recent intelligent tutoring systems were considered just to see how far they are progressing. The average effect size of 1.05 standard deviations for these recent applications is promising. It represents, roughly, an improvement of the performance of 50th percentile students to 85th percentile performance.

The more extensive tailoring of instruction to the needs of individual students that can be obtained through the use of generative, intelligent tutoring systems can only be expected to increase. Such systems may raise the bar for the ultimate effectiveness of ADL instruction.

Student Attitudes

The attitudes of students toward instruction can affect instructional effectiveness and efficiency. Many evaluations of technology-based instruction simply ask students if they prefer it to more conventional classroom approaches. Greiner (1991) reviewed these evaluations and found that typically 70-80 percent of students who were polled preferred technology-based approaches over those that were not. When students report that they do not, the reasons are usually traced to implementation or technical problems with the technology, not the instructional approach itself.

McKinnon, Nolan, and Sinclair (2000) completed a thorough three-year study of student attitudes toward the use of technology-based learning and productivity tools such as spreadsheets, databases, graphics, desktop publishing, and statistical processing. The attitudes of the students toward technology use slackened as the novelty of using the technology wore off. However their attitudes remained positive and significantly more positive than those of students who did not have access to the technology throughout the three years of the study.

Conclusion

The above research data along with other findings, suggest a conclusion that has been called the rule of "thirds." This conclusion states that ADL technologies will reduce the cost of military instruction by about a third and <u>either</u> increase achievement by about a third <u>or</u> decrease time to reach instructional objectives by a third.

In short, the above research suggests that:

- ADL instruction can increase instructional effectiveness.
- ADL instruction can reduce time needed to learn.
- ADL instruction can ensure that all students learn.
- ADL instruction is preferred by students.
- ADL technology is a cost-effective alternative for distributing instruction anytime, anywhere.

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